Massachusetts Institute of Technology
Department of Electrical Engineering and Computer Science

6.200 – Circuits & Electronics
### Spring 2023

Midterm 1

3/8/2023

Name: _____

- There are 6 problems and 24 pages (including this cover page) in this exam.

- Do not remove any pages from this exam.

- Do your work for each question within the boundaries of that question. If you use the back of any pages for work, indicate this fact in text in the valid answer space. Enter your answer to each question in the corresponding answer box provided.

- You may refer to one 8.5"× 11" pages of notes, double-sided. Calculators, smartphones, and laptops are not permitted.

- Show your work. Unless you write out your thought process clearly, partial credit will not be awarded for incorrect solutions.

Problem 1, 16 pts: Hidden Potentiometer

Consider this design of a tunable current source where R_L is the load.
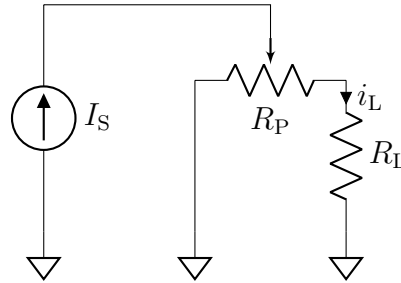
We can redraw the potentiometer as two resistors $(1 - \alpha)R_P$ and αR_P where α is the adjustable parameter.
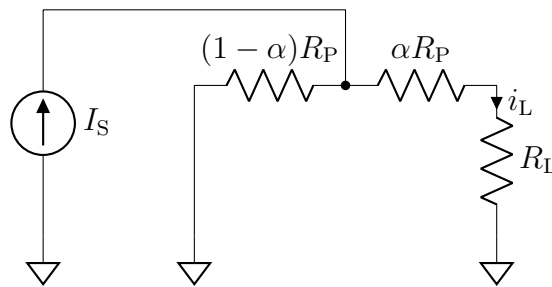
(1A) (4 pt) Assume R_L is 0. Determine the current i_L.

$i_L =$

(1B) (4 pt) Find the current i_L assuming R_L is nonzero.

$i_\mathrm{L} =$

An ideal current source should be able to provide a fixed current to a resistive load, completely independent of the load resistance. In reality, such a perfect circuit is impossible to realize, but it can be approximated.

(1C) (4 pt) A design for a (not tunable) non-ideal current source (providing current i_L to load R_L) is shown in the dashed box below.
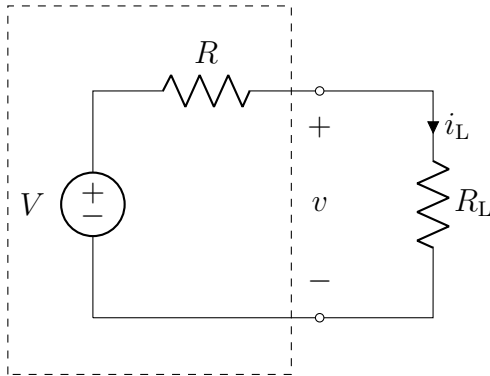

Provide a specific value for V and R where the source supplies consistently approximately $10\,\mu\text{A}$ with variation of less than $\pm 1\%$ (i.e. a minimum of $9.9\,\mu\text{A}$ and a maximum of $10.1\,\mu\text{A}$) even though the load R_L varies from 0 to $10\,\Omega$. V must be less than or equal to $10\,\text{V}$, and R must be between $100\,\text{m}\Omega$ and $100\,\text{M}\Omega$).

$V =$ $R =$

(1D) (4 pt) Finally, we will take the circuit presented in A, using the circuit from part C as the current source. Provide a symbolic expression (i.e. not using the values you chose in part C) for i_L. Note, you may use the notation $R_1//R_2$ to represent resistances in parallel in your answer without penalty.
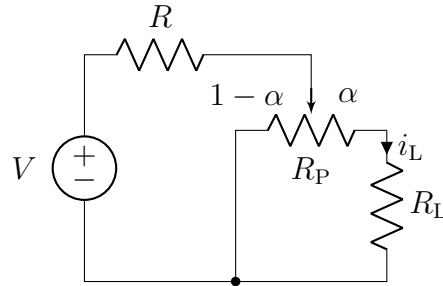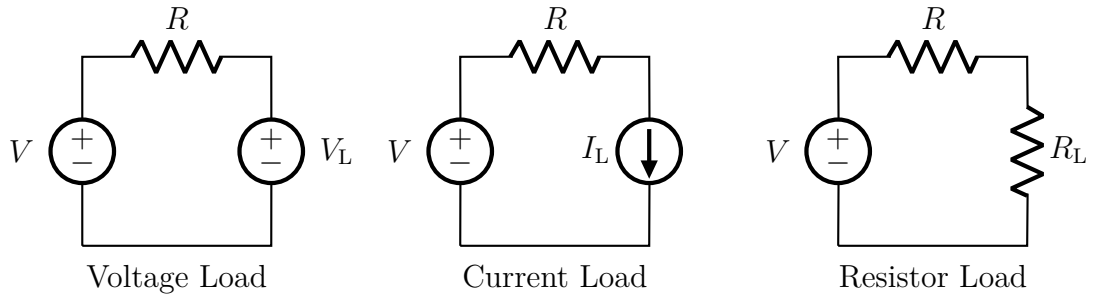

$$i_L =$$

Problem 2, 12 pts: Power

This problem is concerned with determining the value of a load that maximizes the power delivered to that load.

(2A) (8 pt) A Thevenin equivalent network having voltage V and resistance R is separately loaded with a voltage source, a current source, and a resistor, as shown below. For each load case, determine the value of the load (V_L, I_L or R_L) in terms of V and R that maximizes the power delivered to the load. Additionally, determine the maximized power delivered to the load.

Voltage Load   Current Load   Resistor Load
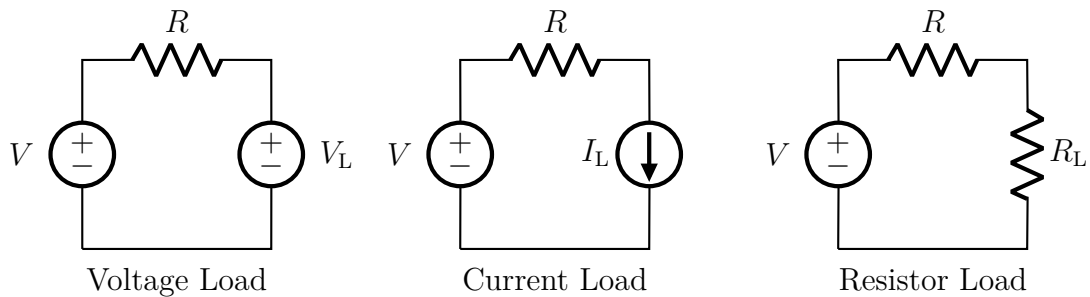
Please put your answers on the following page.

(2A Continued) Circuits repeated for your convenience

$$R$$

$$V \quad V_{\mathrm{L}} \qquad V \quad I_{\mathrm{L}} \qquad V \quad R_{\mathrm{L}}$$

Voltage Load   Current Load   Resistor Load

	V_{L} Load	I_{L} Load	R_{L} Load
Load Value			
Maximized Power			

(2B) (4 pt) The network shown below contains a resistor having an unknown resistance R. Determine the resistance R that maximizes the power dissipated in the corresponding resistor. Additionally, determine the maximized power. *Hint: How are this part and Part A related?*

Numerical values with proper units are expected.
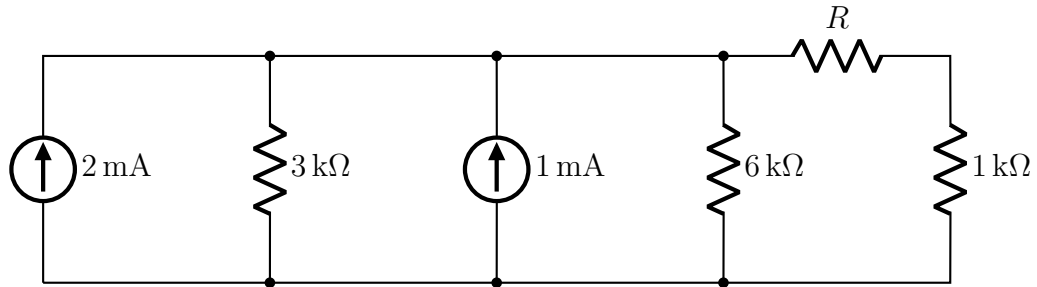
R	Power

Problem 3, 8 pts: Oscilloscope

Provide the requested information for the voltage-time oscilloscope trace shown below:
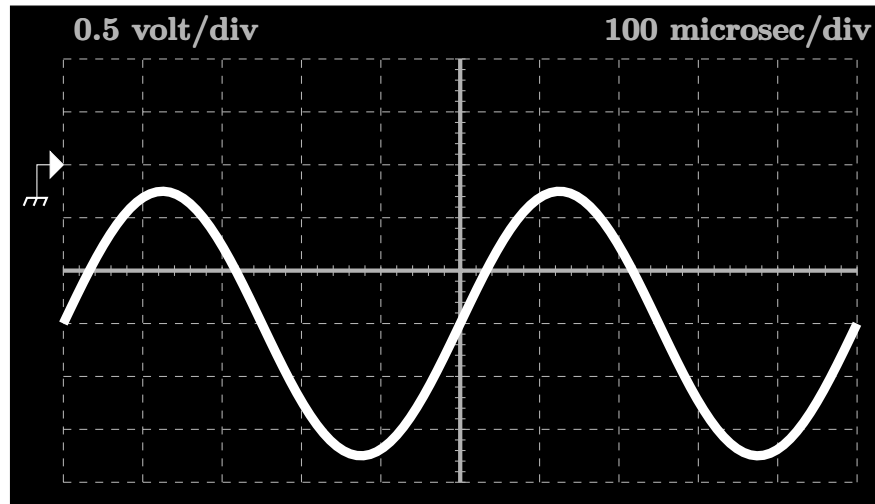
(3A) (2 pt) What is the approximate period T of the signal, with engineering units (i.e. mega, kilo, milli, micro, etc.)?

$T =$

(3B) (2 pt) What is the approximate frequency of the signal, with engineering units (i.e. mega, kilo, milli, micro, etc.)?

frequency $=$

(3) Continued: Oscilloscope image repeated for your convenience.

0.5 volt/div   **100 microsec/div**
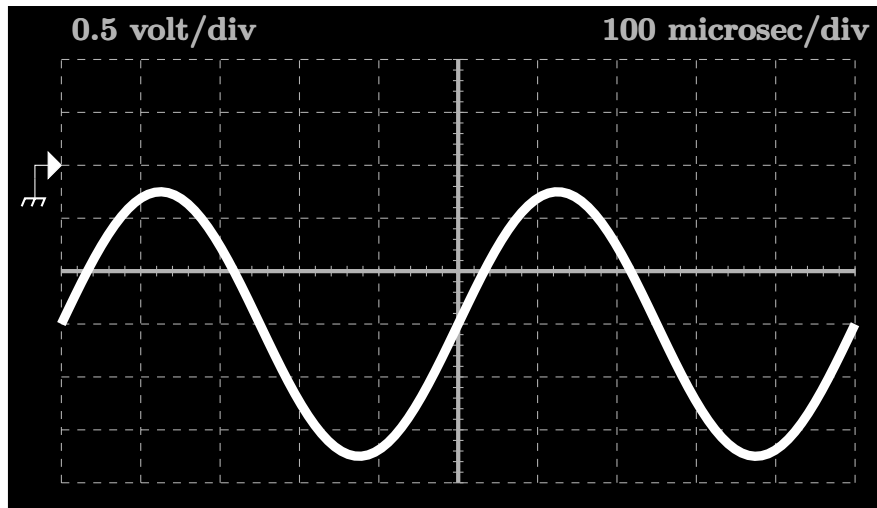
(3C) (2 pt) What is the approximate value of V_{pp} the peak-to-peak voltage of the signal, with appropriate units?

$V_{\mathrm{pp}} =$

(3D) (2 pt) What is the approximate offset of the signal, with appropriate units?

offset $=$

Problem 4, 12 pts: Let There Be Light

In each of the following circuits, is it possible to adjust the positive, finite, non-zero resistances R_1 and R_2 such that the light bulbs have the same voltage drop across them? If so, write *any single* example of a valid combination of R_1 and R_2 in the boxes. If not, write `None` in each box.

We can model each light bulb as a resistor. In each circuit, there are two different bulbs (one with a 10Ω resistance, and one with a 20Ω resistance).

(4A) (4 pt)

R_1: R_2:

(4B) (4pt)

R_1

R_2

$10V$ (+ −) 10V

20Ω

10Ω
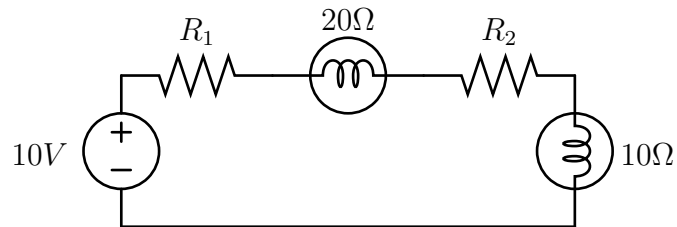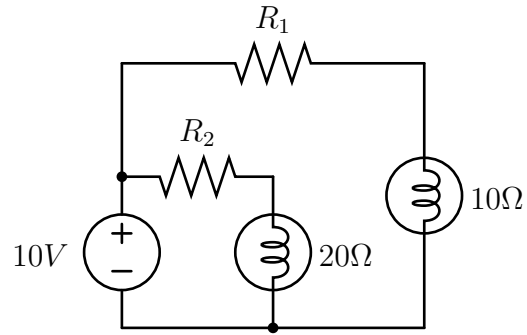
R_1: R_2:

(4C) (4pt)
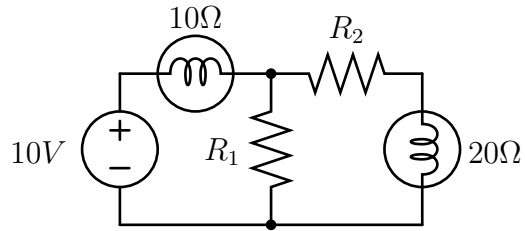
R_1: R_2:

Problem 5, 16 pts: The Turning Po(in)t

In Lab 2, we connected a potentiometer as a voltage divider configuration like the one shown below. In this configuration, v_o and α are related as shown in the graph on the right.
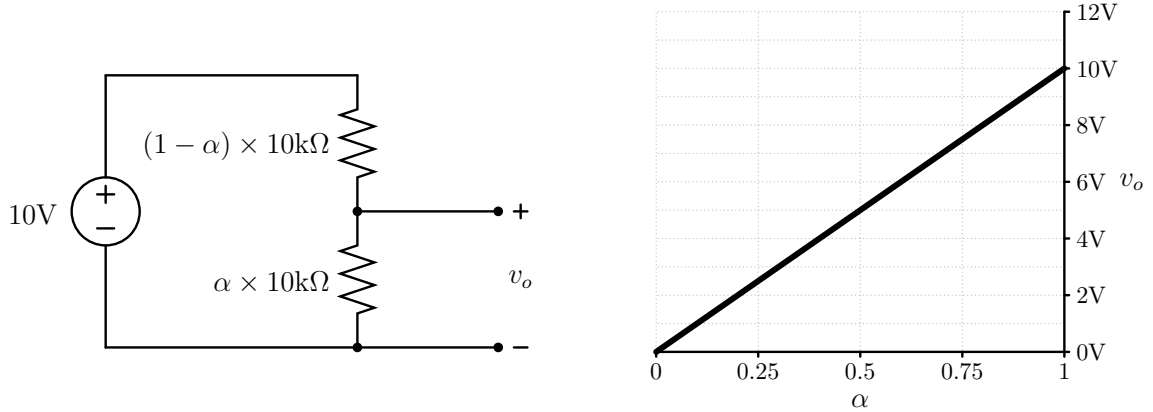
For each of the configurations on the following pages, sketch the relationship between v_o and α in that circuit. The original curve has been reproduced in grey on each graph and can be used as a reference. Note that this pot's total internal resistance is 10kΩ.

(5A) (4pt)

(5B) (4pt)

$(1 - \alpha) \times 10\text{k}\Omega$

10V

$\alpha \times 10\text{k}\Omega$

v_o

2V

$+$

$-$

(5C) (4pt)

10kΩ

$(1 - \alpha) \times 10\text{k}\Omega$

10V

$+$
$-$

$+$

$\alpha \times 10\text{k}\Omega$

v_o

10kΩ

$-$

12V

10V

8V

6V v_o

4V

2V

0V

0   0.25   0.5   0.75   1

α
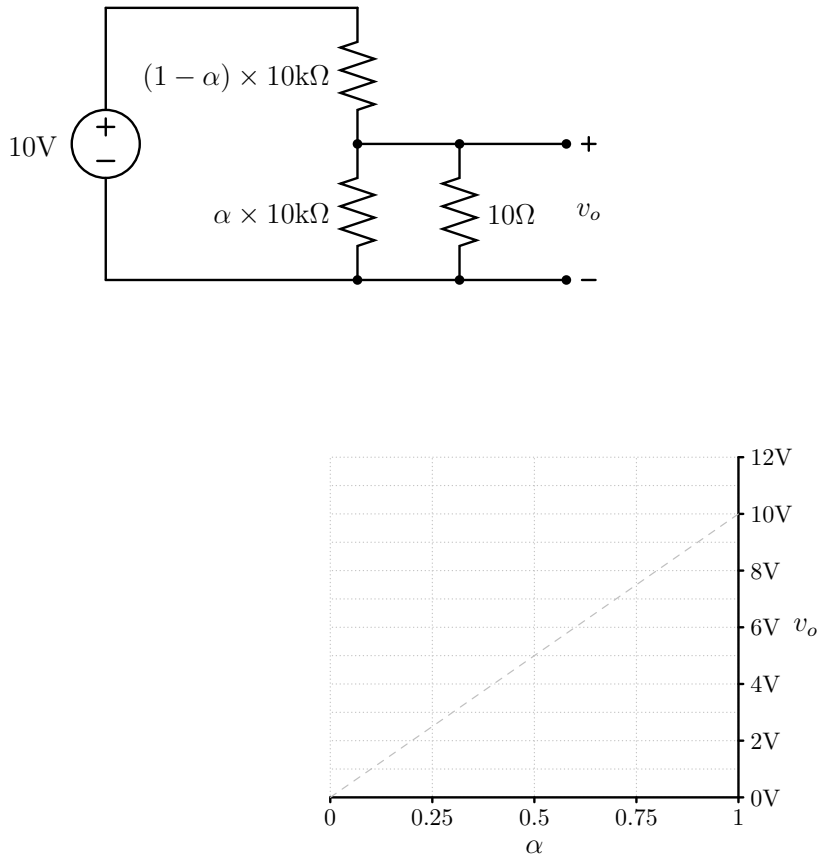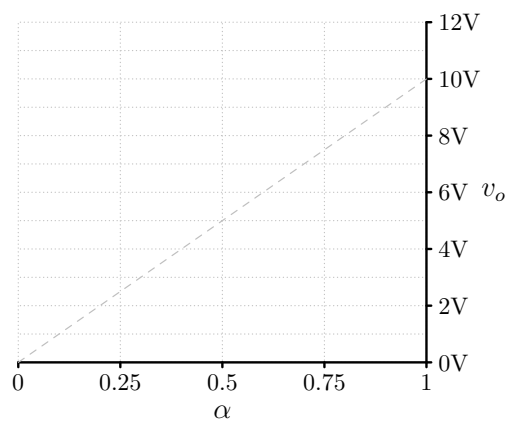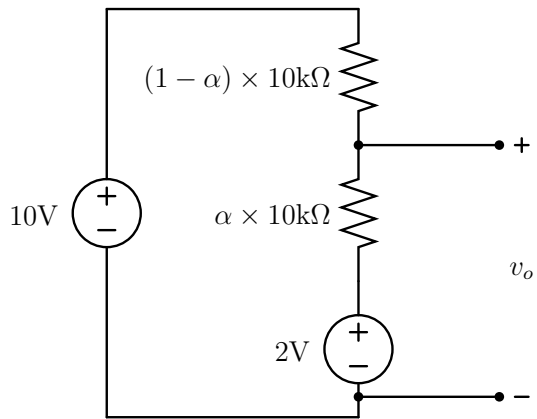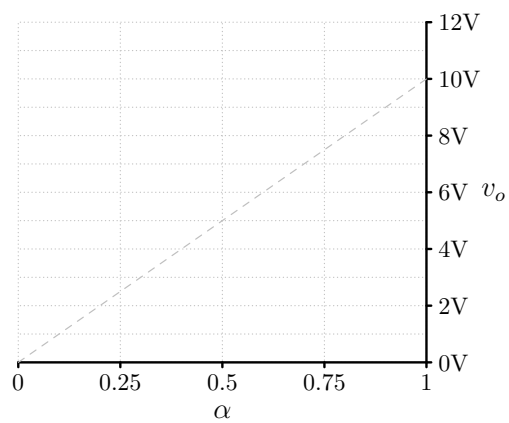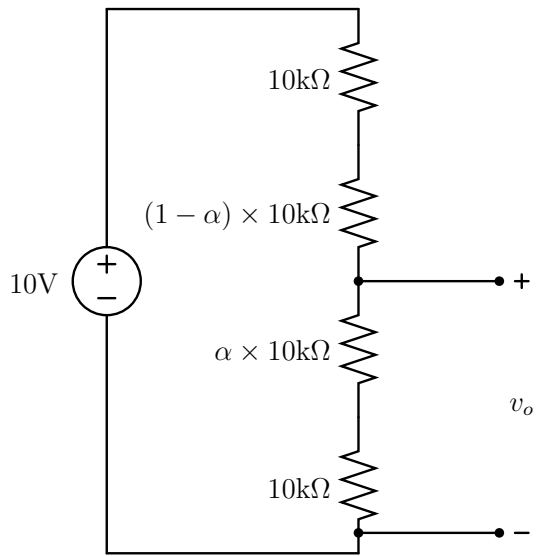
(5D) (4pt)
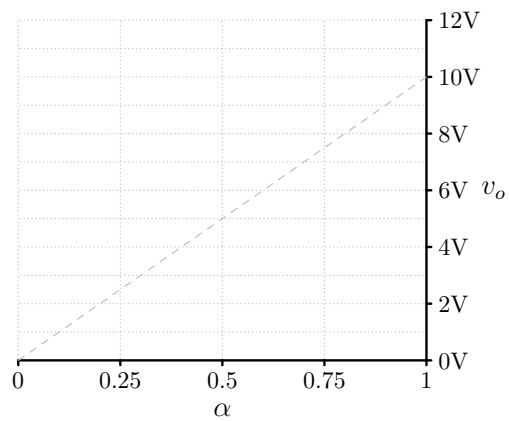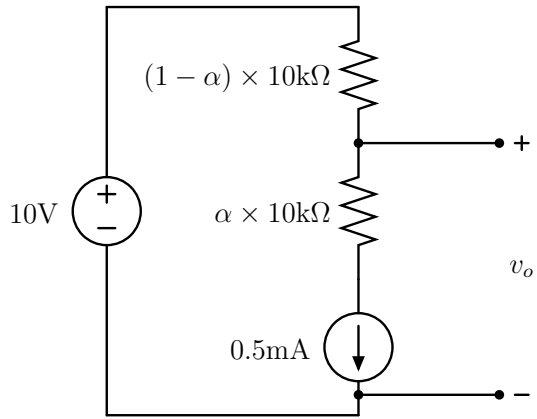
Problem 6, 14 pts: The I-V League

For each of the circuits and current-voltage characteristics shown below and on the following pages (6 in total), specify a single component that could be added in the box to cause the current i and the voltage v to have the pictured relationship. Valid components are limited to:

- resistors with finite positive resistance,
- voltage sources with finite nonzero voltage,
- and current sources with finite nonzero current.

Specify the appropriate component by circling its type and specifying its value (be careful of directionality and specify units!). **If no single component would work, circle "None" and leave the value blank.**

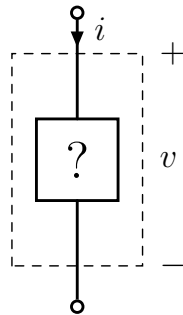Valid circuit elements:
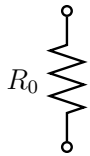
Type: Resistor
Value: R_0
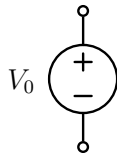
Type: Voltage Source
Value: V_0
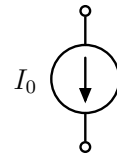
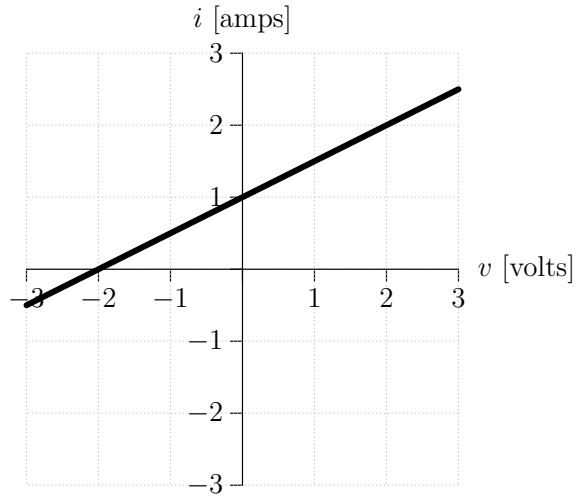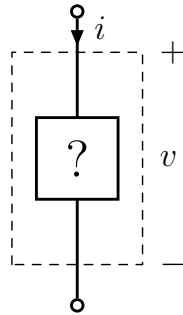Type: Current Source
Value: I_0

(6A) (2pt)
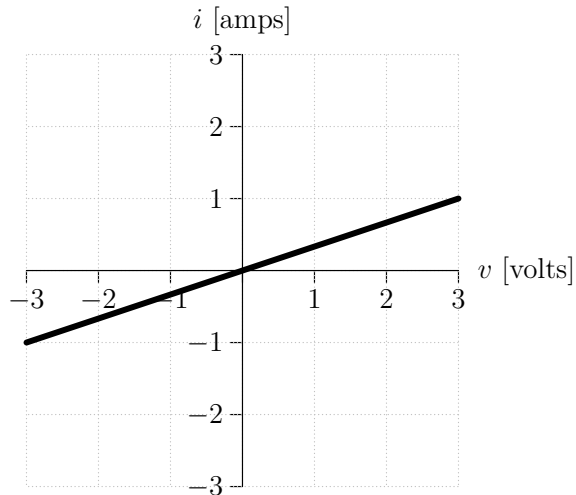
Type (Circle One):	Resistor	Voltage Source	Current Source	None

Value and Units:

(6B) (2pt)

i [amps]

v [volts]

| **Type (Circle One):** | Resistor | Voltage Source | Current Source | None |

Value and Units:

(6C) (2pt)

i [amps]

v [volts]

2Ω

i

$+$

v

$-$

?
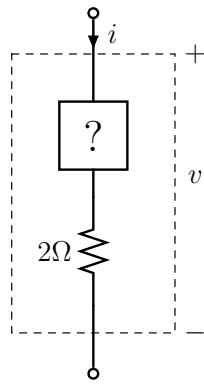
Type (Circle One):	Resistor	Voltage Source	Current Source	None

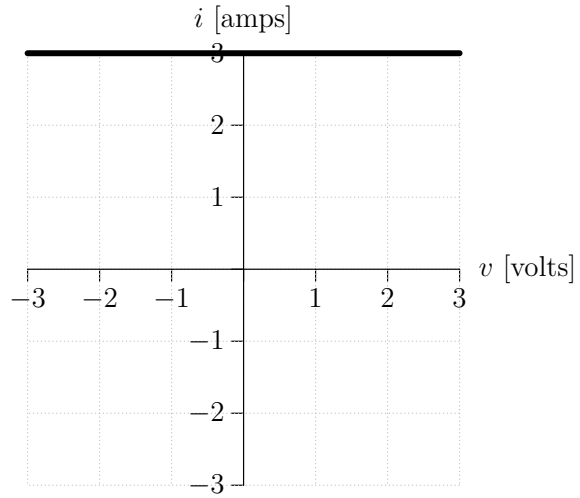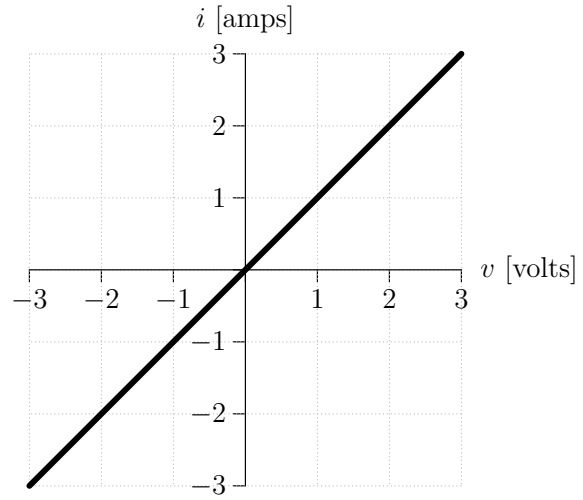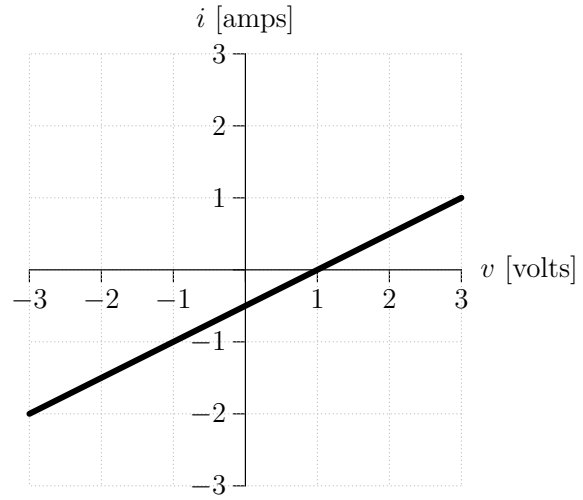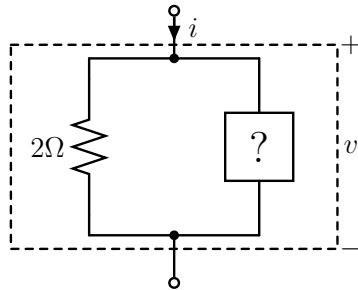**Value and Units:**
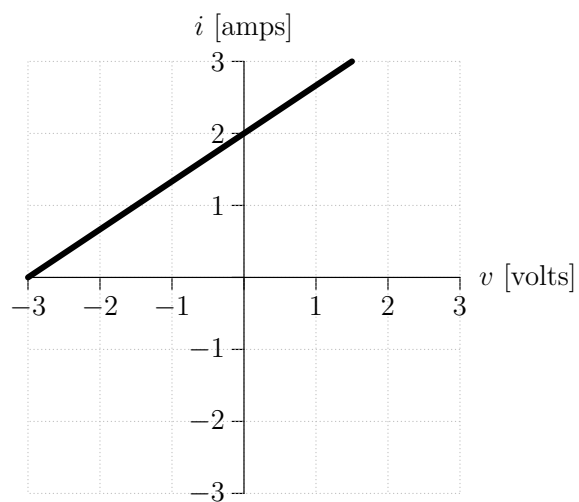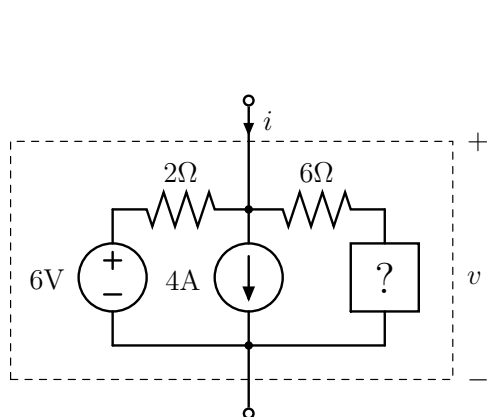
(6D) (2pt)
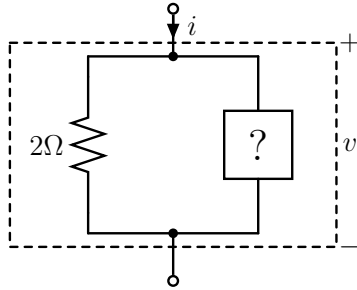
Type (Circle One):   Resistor   Voltage Source   Current Source   None

Value and Units:

(6E) (2pt)

Type (Circle One):   Resistor   Voltage Source   **Current Source**   None

Value and Units:

(6F) (4pt)

i [amps]

v [volts]

2Ω   6Ω

6V   4A   ?

i

v

+

−

Type (Circle One):   Resistor   Voltage Source   Current Source   None

Value and Units:

Worksheet (intentionally blank)